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MELTING AND FIBERIZING MIXTURES OF PELLETIZED BLAST FURNACE SLAG/QUARTZ MIXTURES

by

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SUMMARY

Four pelletized blast furnace slag/quartz mixtures were successfully melted in the CANMET submerged electrode furnace and fiberized. All furnace operations were smooth and quiet with very little fluctuation in voltage and current. Prior to fiberization experiments, electrical resistivity and viscosity, two critical parameters for mineral wool formation, were investigated for typical mixtures. Wool samples at different fiberizing temperatures were collected and the fibre diamters measured by image analysis. The average diameters of the wool samples were mostly in the acceptable range for health and quality standards.

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INTRODUCTION

The mineral wool industry of Canada is composed of many small independent producers that utilize the traditional blast furnace slag/cupola furnace method for mineral insulation production. The cupola has a number of disadvantages:

1. It is considered to be energy inefficient.
2. The chief source of fuel, coke, must be imported and is increasing in price.
3. Raw material must be in a lump or pelletized form to reduce material loss up the stack and to allow free passage of air and combustion gases.
4. Waste shot, which is less than 3 mm in diameter and usually accounts for 30 to 40% of the melt, is non-recyclable.
5. Sulphur contained in the raw materials, e.g., in coke and slag, is converted into H_2S, SO_2 or SO_3 and may cause environmental problems.

Good quality mineral wool is produced in several European countries using more energy efficient and environmentally acceptable electro-melt techniques. Additional advantages of electro-melting are that homogeneity and composition of the charge are more easily controlled. Fine as well as coarse raw materials may be melted, thus recycling of waste shot is feasible. However, electric furnaces must be located near abundant and inexpensive electric power sources.

The CANMET mineral insulation project is designed to evaluate electro-melt techniques for the production of mineral wool from blast furnace slag, and, as well, from alternative materials such as diopside, basalt, and trap rock. This report outlines work undertaken with the electric melt furnace utilizing blast furnace slag as the principal feed material.

EXPERIMENTAL WORK

A three electrode, 150 kVA electric-arc furnace was installed and commissioned at CANMET in 1979 (1). The furnace uses graphite crucible to

hold the charge and includes a mechanism to allow bottom gravity flow of the glass melt. A kWh meter was used to determine energy consumption during the melting process and also to establish the relationship between feed, feed rate, and electrical energy consumption. The furnace is described in detail in Reference 1.

The fiberizing apparatus (air jet) designed and used for this work consisted of a venturi type nozzle with an oval-shaped opening that measured 1.6 x 20.6 mm. This was placed with the longer axis (20.6 mm) horizontal and at right angles to the flow of molten glass approximately 25 mm below the bottom of the tap hole and 25 mm from the stream. Compressed air fed through the nozzle dispersed the stream into fine globules which were attenuated into fibres by the air resistance during flight.

SAMPLES

Samples of pelletized blast furnace slag from Hamilton, Ontario, were mixed with quartz from Baskatong, Quebec, to give mass ratios of 4.5:1, 4:1, 3.5:1 and 3:1 respectively. The chemical analysis of the slag and the calculated compositions of the charge mixtures are shown in Table 1.

Table 1 - Chemical composition of samples

Sample	Mass ratio of slag to quartz	CaO	SiO_2	Al_2O_3	MgO	Total Fe	Acid/base ratio
slag	1:0	35.1	40.4	7.0	12.8	0.85	0.89
quartz	0:1	-	99.9	-	-	-	-
1	3:1	26.3	55.3	5.3	9.6	0.64	1.65
2	3.5:1	27.3	53.6	5.4	10.0	0.66	1.55
3	4:1	28.1	52.3	5.6	10.2	0.68	1.48
4	4.5:1	28.7	51.2	5.7	10.5	0.70	1.42

The acid/base ratio was calculated as follows:

acid/base ratio = (wt % SiO_2 + wt % Al_2O_3) / (wt % CaO + wt % MgO + wt % FeO) (1).

Previous experiments showed that good fibre was produced with charge materials having an acid/base ratio of 1.5 (2).

PROCEDURE

A 5-8 cm layer of blended charge materials (2.3 kg) was placed in the bottom of the crucible and topped by a thin layer of minus 6 mm coke. The coke, used to initiate the electrical arc, covered an area large enough to engage all three electrodes. The power was turned on and the crucible raised until the arc was established. As the arc initially heated and then melted the solid materials, the volume of the charge decreased. Arcing was maintained by raising the crucible. When a molten pool of material was formed, the electrodes were immersed in the melt which then became an ionic conductor. The unit then functioned as a resistance-heating furnace. The depth of the molten bath was increased by feeding the remaining 6.7 kg of the charge through the feeder port continuously over a 20-25 min period.

The power consumption, indicated by the kWh meter and directly related to the actual amount of heat input into the charge materials, was used to determine when the approximate desired temperature had been reached. At this point the power was shut off and the crucible quickly lowered. An immersion-thermocouple-lance was used to measure the melt temperature. The crucible was then raised and the required temperature reached by either continuing to supply electrical power to the furnace or by allowing the furnace charge to cool. The melt temperature was closely monitored during this critical period.

When the desired temperature was reached, a graphite plug in the bottom of the furnace was "punched" through the tap hole. The melt temperature was monitored by an optical pyrometer as the melt flowed through the hole. The stream of molten material was subjected to an air-blast at right angles to the stream, at a pressure of 620 kPa and at a flow rate of 1.2 m^3/min. Fiberization took place as the liquid globules formed by the impact were drawn out by air resistance during flight. The stream of wool was sampled at different fiberization temperatures by a hand-held sampler net. The bulk of wool was deposited in the collecting chamber.

RESULTS AND DISCUSSION

Before conducting the fiberization experiments, two critical parameters of the melt were investigated, namely, electrical resistivity and vis-

cosity. Electrical resistivity of the melt influences the energy dissipation and determines the positioning of the electrodes in the furnace. Information of this parameter is essential for efficient and smooth operation of the furnace. Viscosity data serve to give some indication of the proper fiberizing temperature. Fibre diameter is dependent on melt viscosity. A viscous melt produces fibres that are coarse, harsh and brittle. By contrast, a low-viscosity stream produces wool that is fine, short and fluffy, but with very poor felting qualities (3).

ELECTRICAL RESISTIVITY

The electrical resistivities of the 3:1 slag/quartz mixture were measured using a 4 probe system under an EMR contract (4). Table 2 and Fig. 1 show the experimental results. Electrical resistivity of molten silicates depends not only on the number of ions present, but also on their mobility which is a function of their size and of melt viscosity. The resistivity will decrease as temperature increases as indicated in Fig. 1.

Table 2 - Electrical resistivity measurements

Temperature °C	1287	1338	1438	1480	1485
Electrical resistivity (ρ), Ω.cm	36.0	21.0	11.0	8.0	6.8

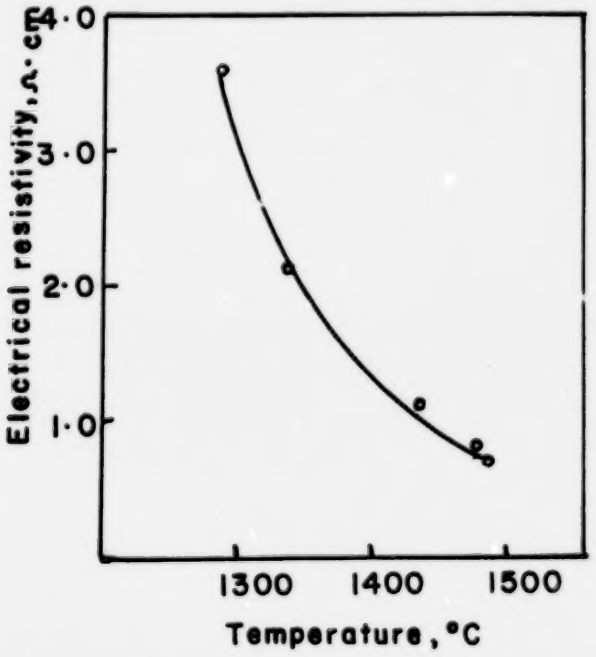

Fig. 1 - Electrical resistivity as a function of temperature

The furnace operations during the melting of the four samples were very smooth and quiet with no arcing problem and very little voltage and amperage fluctuations, an indication that all four melts were good ionic conductors.

VISCOSITY

The viscosities of samples 1, 2 and 3 had previously been measured at various temperatures by a high-temperature viscometer (5). The results are presented graphically in Fig. 2. Viscosity decreases as temperature increases. It is well accepted that viscosity depends on the size of the largest species in the melt i.e. the silicate anions. An increase in temperature causes progressive loosening of the silicate network structure by thermal agitation. This action decreases viscosity.

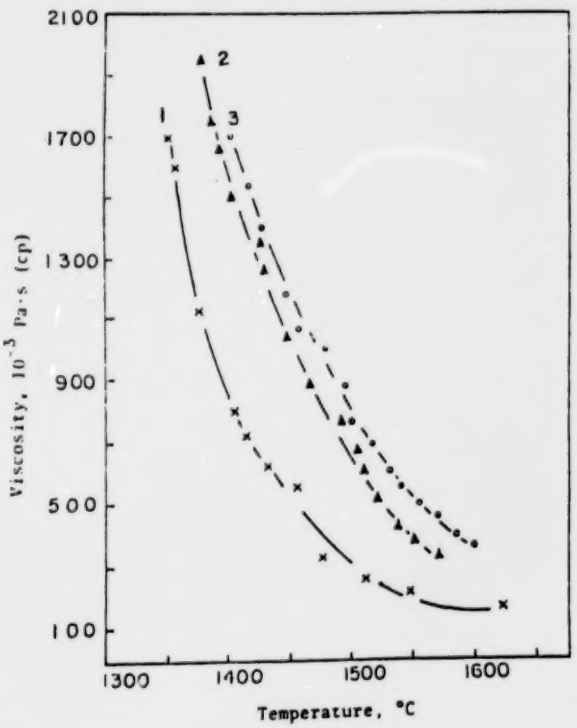

Fig. 2 - Viscosity as a function of temperature, samples 1 to 3.

Zhilin observed that good quality fibre was obtained when the viscosity of the melt was about 500 cp (centipoise, 10^{-3} Pa.s) at 1500°C, or 1500 cp at 1400°C (6). The experimental data in Fig. 2 show that the viscosities range from 300 to 800 cp at 1500°C and from 850 to 1700 cp at 1400°C.

Therefore, some of the samples used in this study should produce acceptable fibres.

FIBERIZATION AND FIBRE DIAMETER MEASUREMENT

All products were white in colour and, as per an initial visual/handling examination, of fair quality.

The small size of the electric furnace used in this study limits the charge to about 9 kg; furthermore, high and progressive heat losses are experienced in the melt during tapping operations. The net effect is that only small quantities of wool are produced at specific fiberizing temperatures. The wool sample usually amounted to 10-15 g and was much less than the size required for thermal conductivity measurement by, for example, the guarded hot plate method. The only meaningful characterization test of the wool samples under the circumstances was measurement of fibre diameters. The fibre diameters were measured by image analysis with a Quantimet 720 image analyzer (7).

A summary of the results is shown in Table 3. Median diameter is

Table 3 - Fibre diameter

Sample charge	Fiberizing temperature °C	Median diameter µm	Average diameter µm
1	1470	7.5	8.2
	1455	8.2	9.3
	1440	15.0	17.3
2	1535	2.9	3.2
	1505	3.6	4.1
	1490	4.6	4.9
	1415	8.7	9.7
3	1420	3.3	3.9
	1360	5.4	5.4
4	1480	8.4	9.4
	1450	16.0	18.4
	1405	17.5	19.5

the point below which 50% of the fibres occur. For each sample charge, both average and median diameters increase as fiberizing temperature decreases. As previously discussed, when temperature decreases, melt viscosity increases and coarser fibre is produced.

Mineral wool having a diameter of 2-7 μm is soft and possesses a certain degree of resiliance. However, fibres of smaller diameters tend to pack more closely. The non-conducting air space is decreased but the bulk density of the wool is increased. Too fine a fibre may also present a health hazard. Coarser fibre wool, however, is more brittle, bulky and unpleasent to handle and has larger air pockets formed by the interlacing fibres causing heat loss by convection. A reasonable compromise for acceptable wool fibre diameters would be from 3 to 12 μm. An examination of Table 3 indicates that fibres produced for charge mixture 1, at 1440°C, and for charge mixture 4, at 1450 and 1405°C, are definitely too coarse. The average diameters of the other wool samples are in the acceptable range for health and quality as discussed above.

CONCLUSIONS

In this series of tests, four mixtures of blast furnace slag-quartz were melted in the CANMET submerged electrode furnace. All the furnace operations were smooth and quiet. All four melts were successfully fiberized by blowing with compressed air. The average fibre diameters indicated that most of the wool samples produced were of acceptable quality. This study demonstrates that acceptable mineral wool fibre can be produced by electromelting. It therefore appears to be a suitable alternate process for mineral wool production.

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REFERENCES

1. Winer, A.A., Wang, S.S.B. and Sirianni, G.V. "Commissioning of a special electric smelting furnace for production of mineral thermal insulation"; Division Report MRP/MSL 79-99 (IR); CANMET, Energy, Mines and Resources Canada; 1979.

2. Unpublished information; CANMET.

3. Gillespie, J.E. "The manufacture of mineral wool"; Can Min Metall Bull 41:20-24; 1948.

4. Reyes, J.M. "A study of the high temperature electrical conductivities of silicate samples - molten state"; Ontario Research Foundation; 66001; 1980.

5. Quon, D.H.H. and Wang, S.S.B. "Viscosity - temperature relationships of blast furnace slag, asbestos tailings and silica mixtures"; Division Report MRP/MSL 81-14 (IR); CANMET, Energy, Mines and Resources Canada; 1981.

6. Zhilin, A.I. "Raw materials for the production of mineral fibres"; J Appl Chem USSR 23:11:1157-1164; 1950.

7. Petruk, W. "Image analysis of mineral wool fibres produced in the Mineral Processing Laboratory"; Division Report MRP/MSL 80-102 (IR); CANMET, Energy, Mines and Resources Canada; 1980.